[redacted]

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E, Par. 5.1	22	LEM	NAS 9-1100	1/15/63

TYPE II DATA

Primary Code 910

REPORT

Copy #7

NO. LED-2-4'B'

DATE: 1 August 1963
Rev. 15 January 1964

LEM REQUIREMENTS FOR THE
STATIC TEST [redacted]
AT AM[redacted]

CODE 26512

AMR Facilities Committee

PREPARED BY: ETB
E. T. Barron, Chairman

T. H. Moorman

CHECKED BY:
T. H. Moorman
M. H. Dandridge

J. Walsh

APPROVED BY:
J. Walsh

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS
1/15/64	ETB	COMPLETE REVISION	

This document [redacted]

[redacted]

ABSTRACT

The facilities planned in reference (a) for the Static Test Site at AMR for acceptance firing the LEM propulsion subsystem are adequate, with the exception of the Static Test Site control building; which is marginally adequate for housing the control equipment. The equipment required for the checkout operation at this site is included in this report, with layouts of the equipment in the planned buildings for the site.

ABSTRACT

The facilities planned for the Static Test Site at AMR for acceptance firing the LEM propulsion subsystem are adequate, with the exception of the Static Test Site Control Building; which is marginally adequate for housing the control equipment. The equipment required for the checkout operation at this site is included in this report, with layouts of the equipment in the planned buildings for the site.

REFERENCES

a. MSC-AMR Operations - Criteria for Design - MSC Static Test Facility - Preliminary. 11 Dec 1963

b. GAEC Report No. LED-2-2 - Technical Criteria for Altitude Simulation System for Apollo LEM Test Facility, NASA, MSC Test Area, WSMR - 17 June 1963.

c. U.S. Army Engineer District, Albequerque - Corps of Engineers Albequerque, New Mexico - Specifications for Construction of LEM Test Facilities, NASA/MSC - WSMR, New Mexico Specfication #ENG (NASA) 29-005-64-3 Amendment #4 "Altitude Simulation System" 12/27/63.

d. U.S. Army Engineer District, Albequerque - Corps of Engineers, Albequerque, New Mexico. "Specifications for Altitude Simulation Chamber LEM Test Facilities, NASA, MSC-WSMR, New Mexico" 11/1/63.

REFERENCES

a. MSC-AMR Operations - Criteria for Design - MSC Static Test Facility - Preliminary. 11 Dec 1963

b. GAEC Report No. LED-2-2 - Technical Criteria for Altitude Simulation System for Apollo LEM Test Facility, NASA, MSC Test Area, WSMR - 17 June 1963.

CONTENTS

CONTENTS - continued

1.0 INTRODUCTION

Static firing of the LEM engines utilizing each complete LEM will be performed as part of the prelaunch acceptance tests at AMR to insure proper operation of the LEM system and the propulsion subsystem. LEM requirements for the Static Test Site to perform these tests have been summarized and are presented herein. The technical criteria for the required altitude simulation system and engine parameters for the ascent and descent engines are presented in Appendix 'A'. Engine parameters and data which affect the design of a separate exhauster or collector system for the reaction control subsystem are presented in Appendix 'B', in the event that the RCS engines are acceptance fired at the Static Test Site.

It appears most desirable that the equipment, facilities, and methods developed for use at WSMR in the development program be duplicated where possible and used at AMR for the acceptance tests of the propulsion and reaction control subsystems. This is the philosophy which has been used in determining the facilities and equipment required at the Static Firing Site at AMR.

2.0 DISCUSSION

2.1 General: The requirements for the LEM at the Static Test Site at AMR are comprised of the equipment required to perform the acceptance tests of the propulsion subsystem, the services required for the equipment and tests, and the facilities required at the site for performance of the tests. The acceptance tests currently planned to be conducted at the LEM Static Test Site include tests on the ascent and descent engines with all subsystems operating which are in the ascent or descent engine firing loop. For example, the N & G and S & C subsystems will be operating during the descent engine firing since signals from these subsystems control the thrust and gimballing of the descent engine. The reaction control subsystem may be acceptance tested at the Static Firing Site. The need for hot firing tests of the RCS at the Static Firing Site has not been completely defined at this time. The possibility does exist, however, that the RCS flight nozzles cannot be adequately acceptance fired at sea level. There is also the possibility of a conflict in scheduling the use of the hypergolics building between the currently planned space programs at AMR. For these reasons, this report makes provisions for firing the RCS at the Static Test Site. The equipment required for the RCS has been included in the equipment lists and on the layouts.

There is a potential need for a collector system or a separate exhauster system for each RCS quad if the RCS is fired in the altitude chamber of the Static Test Site. One of these systems

2.0 DISCUSSION

2.1 General - continued

would be required to prevent the corrosive unburned gases from damaging the ascent stage of the LEM vehicle during firing. An exhauster system would be required if the RCS was fired at altitude. Firing the RCS at sea level would not require an exhauster system, but would require a collecter system for the unburned corrosive gases.

The site plan presented in reference (a) has been reviewed to compare the facilities planned with those required for the planned acceptance tests. The facilities described in reference (a) are sufficient for the tests planned at the Static Test Site. A conceptual layout of the site appears on figure 4.2, with the servicing equipment located in the vicinity of the altitude chamber.

2.2 Equipment Required at the Static Firing Site

Fluid Systems GSE

The fluid system equipment listed in table 3.1 is required for servicing the propulsion and reaction control subsystems, and for checkout prior to actual engine firing. This equipment will be located on the pad adjacent to the altitude chamber as shown on figure 4.2.

Handling and Transportation GSE

The equipment listed in table 3.2 is required for transporting and handling the ascent stage, descent stage, and mated LEM at the Static Test Site. A crane or gantry with a 10-ton capacity will be required for handling the mated LEM vehicle.

Within the altitude chamber there need be only two positions for supporting the LEM; these are: (1) Support of the mated ascent and descent stages for descent engine firing; (2) Support of the ascent stage alone for ascent engine and/or reaction control subsystem operation. A smaller crane with a 3 ton capacity will be required for installing and removing equipment and the LEM support mounts. This crane must have access to the inner periphery of the altitude chamber.

Electrical GSE

The equipment listed in table 3.3 will be required for the control of the engine firing. Most of this equipment is similar to that required at WSMR for controlling engine firing during propulsion development tests. The LEM's at AMR, however, will contain complete subsystems which will not be used in the early development tests at WSMR. The

2.0 DISCUSSION

2.2 Equipment Required at the Static Firing Site

Electrical GSE - continued

GSE listed in table 3.3 has been laid out in the control room of the Static Test Site (figure 4.4) and will operate by utilizing, as much as possible, the actual LEM engine controls and related subsystems.

The facility control equipment (TV control station, altitude simulation control station, etc.) has also been laid out in the area allotted for the LEM control room (Figure 4.4). It should be noted that the area has been completely utilized and does not provide for any growth of planned equipment. An additional 300 square feet is desirable to allow for additional equipment or possible growth of currently planned equipment.

PACE downlink will be used for data acquisition. A certain number of critical parameters will, however, be hardlined to the control building for monitoring during firing. The instrumentation readout equipment for this purpose has been laid out in Figure 4.4. The PACE carry-on equipment will be located either inside the LEM vehicle or adjacent to the LEM within the altitude chamber. The data interleaver will be located in the transfer building, as shown in figure 4.3.

2.3 Special Requirements: Altitude simulation is required for acceptance tests of the LEM propulsion subsystem. The technical criteria for this required altitude simulation system are described in Appendix A of this report and are very similar to that required for WSMR (presented in reference (b)). Also, see (c) and (d).

It is necessary that the lower end of the ascent engine skirt fit into the diffuser at the bottom of the altitude chamber. This may require an extension to the altitude chamber diffuser since the ascent stage will sit above the diffuser (due to the fixed supports). This extension should bridge the gap between the lower end of the ascent engine and the diffuser.

Within the altitude chamber external power will be used to power the LEM system. Power requirements will include 28 volt DC and 105/125 volts AC, 60 cps, 1ϕ.

Code 26512 Eng-23A

2.0 DISCUSSION

2.2 Equipment Required at the Static Firing Site

Electrical GSE - continued

GSE listed in table 3.3 has been laid out in the control room of the Static Test Site (figure 4.4) and will operate by utilizing, as much as possible, the actual LEM engine controls and related subsystems.

The facility control equipment (TV control station, altitude simulation control station, etc.) has also been laid out in the area allotted for the LEM control room (Figure 4.4). It should be noted that the area has been completely utilized and does not provide for any growth of planned equipment. An additional 300 square feet is desirable to allow for additional equipment or possible growth of currently planned equipment.

PACE downlink will be used for data acquisition. A certain number of critical parameters will, however, be hardlined to the control building for monitoring during firing. The instrumentation readout equipment for this purpose has been laid out in Figure 4.4. The PACE carry-on equipment will be located either inside the LEM vehicle or adjacent to the LEM within the altitude chamber. The data interleaver will be located in the transfer building, as shown in figure 4.3.

2.3 Special Requirements: Altitude simulation is required for acceptance tests of the LEM propulsion subsystem. The technical criteria for this required altitude simulation system are described in Appendix A of this report and are very similar to that required for WSMR (presented in reference (b)).

It is necessary that the lower end of the ascent engine skirt fit into the diffuser at the bottom of the altitude chamber. This may require an extension to the altitude chamber diffuser since the ascent stage will sit above the diffuser (due to the fixed supports). This extension should bridge the gap between the lower end of the ascent engine and the diffuser.

Within the altitude chamber external power will be used to power the LEM system. Power requirements will include 28 volt DC and 105/125 volts AC, 60 cps, 1ϕ.

Code 26512 Eng-23A

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

LEM EQUIPMENT - STATIC FIRING FACILITY - AMR

AREA: GSE & TRANSFER BUILDING

TABLE 3.1

PART NUMBER	NOMENCLATURE	NO REQ'D	TYPE OF INSTALL.	FLUID REQ'D	POWER REQUIRED	SIZE H	SIZE W	SIZE D	WT. (lbs.)	REMARKS
430-62160	Checkout Unit - Propulsion	1	Mobile	Helium	120/208 V AC, 3ϕ, 4 Wire	6'	6'	10'	3000	6000 psi Helium Source
430-62180	RCS, Checkout Chart	1	Mobile	Helium		4'	8'	4'	3000	
430-62460	Control Unit, Fuel Transfer, RCS	1	Mobile		115 V AC, 28 V DC	36"	48"	36"	200	
430-94063	RCS Fuel Servicing Unit	1	Mobile	N_2 Hydroxyacetic	115 V AC, 28 V DC	6'	10'	4'	2500	
430-94057	RCS Oxidizer Service Unit	1	Mobile	Triethanolamine, N_2	115 V AC, 60 Cycle	6'	10'	4'	2500	
430-62500	RCS Oxidizer, Transfer	1	Mobile		115 V, 60 Cycle AC	3'	4'	2'	250	
430-94060	Vapor Disposal Unit, Fuel	1	Mobile		480 V, 60 Cycle 3ϕ, 60 Amps	96"	168"	120"	4000	
430-94058	Fuel Ready Storage Unit	1	Mobile	N_2	120/208 V AC, 3ϕ, 4 Wire	6'	6'	12'	4000	2000 psi
430-94059	Oxidizer Ready Storage Unit	1	Mobile	N_2O_4	120/208 V AC, 3ϕ, 4 Wire	6'	6'	12'	4000	2000 psi
430-64420	Control Unit, Fuel Ascent & Descent	1	Mobile	GN_2	120/208 V AC, 60 Cycle, 3ϕ	30"	18"	48"	150	
430-94019	Service Unit Water Glycol	1	Mobile	Nitrogen	480 V AC, 3ϕ, 60 Cycle, 208/220 V AC	72"	40"	80"	2000	
430-94003	Mass Spectrometer, L.D. Helium		Mobile	Helium	115 V, 60 Cycle, 30 Amps	80"	42"	34"	550	Height with Bell Jar
430-94009	Transfer & Conditioner, Helium	1	Mobile	LN_2	120/208 V AC, 3ϕ, 4 Wire, 28 V DC	60"	48"	72"	2000	
430-94022	Helium Booster Unit	1	Mobile	Water	227/480, 3ϕ, 4 Wire, 120/208 3ϕ, 4 Wire	60"	60"	100"	3000	Boost Helium From 2200 psi to 6000 psi
430-94062	Helium Ready Storage Unit	1	Mobile	Helium		8'	8'	23'	40000	
430-94002	Oxidizer Transfer & Condit. Unit	1	Mobile	Nitrogen	480 V AC, 60 Cycle, 3ϕ, 150 Amps	96"	96"	168"	8000	(22000 Fully Loaded)
430-94008	Fuel Transfer & Condit. Unit	1	Mobile	Aerozine 50	120/208 V AC, 3ϕ, 4 Wire	5'	6'	10'	2000	
430-94061	Oxidizer Toxic Vapor Disposal	1	Mobile		480 V AC, 60 Cycle, 3ϕ, 60 Amps	96"	168"	120"	4000	
430-94070	Engine Decontamination Unit	1	Mobile	N_2	120/208 V AC, 3ϕ, 4 Wire	6'	8'	10'	2000	Flushing Fluids 2000 psi
430-64460	Oxidizer Propulsion Panel	1	Mobile	Nitrogen	120/208 V AC, 60 Cycle, 3ϕ	30"	18"	48"	150	
430-62520	Cart, Oxidizer Flush & Purge, RCS	1	Mobile	N_2 + Trieth.	115 V AC, 60 Cycle	6'	10'	4'	2500	
430-62480	Cart, Fuel Flush & Purge, RCS	1	Mobile	N_2 + Hydroxyacetic	115 V AC & 28 V DC	6'	10'	4'	2500	
430-64220	Helium Pressure Distribution Unit									Data Not Available

LEM EQUIPMENT - STATIC FIRING FACILITY - AMR

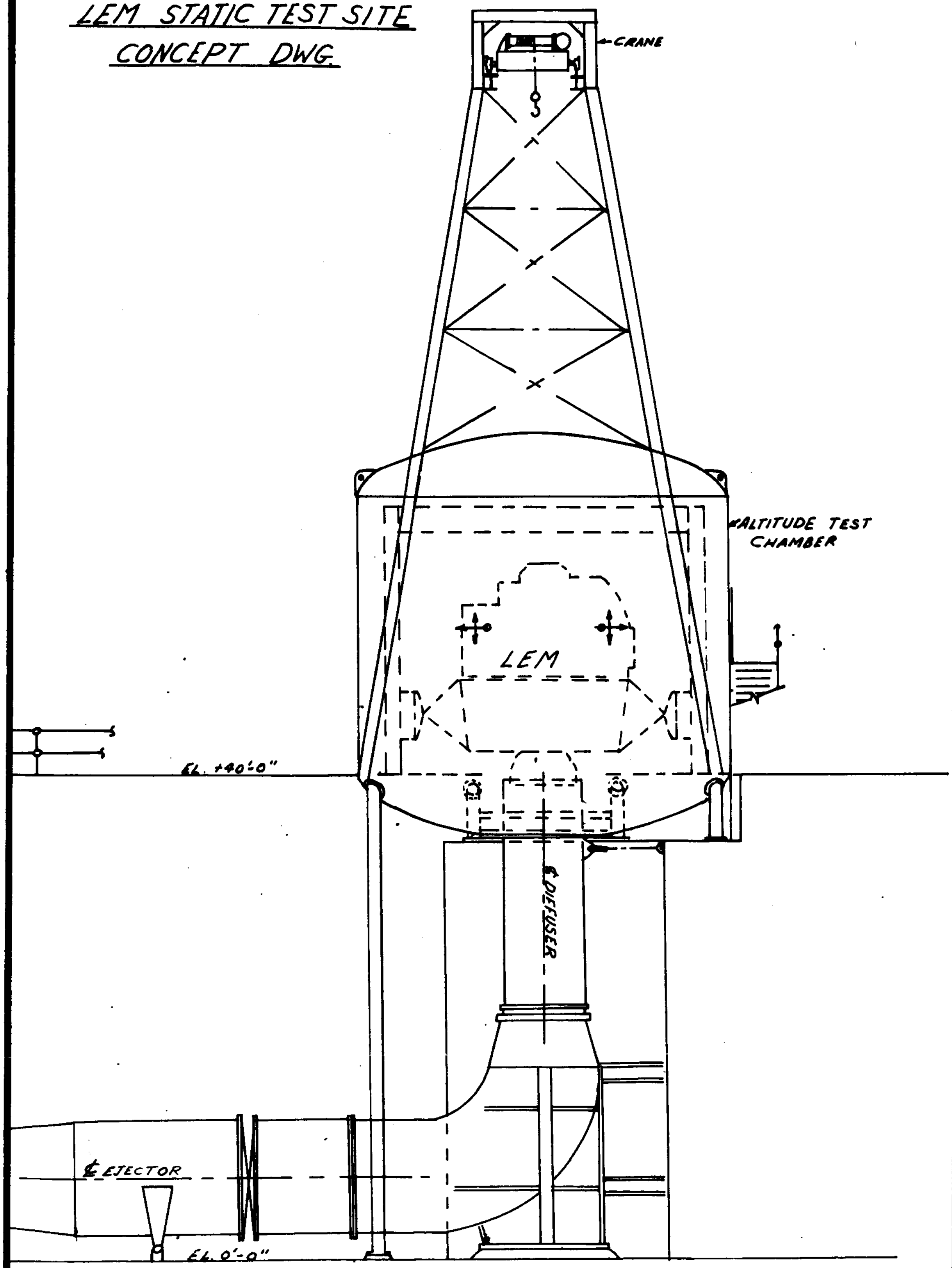
PART NUMBER	AREA: STATIC FIRING STAND NOMENCLATURE TABLE 3.2	NO REQ'D	TYPE OF INSTALL.	FLUID REQ'D	POWER REQUIRED	SIZE H	SIZE W	SIZE D	WT. (lbs.)	REMARKS
	Test Stand Frame (inside chamber)	1	Fixed			10'	16'	16'	15000	Supports Vehicles (LEM) during static firing tests
	Platform Set (workstand, inside chamber)	1	Fixed			10'	175"	175"	1500	Allows personnel to reach LEM access areas within firing chamber.
	D/S Hard Mount Adapter (inside chamber)	4	Removable			40"	40"	36"	400	Connects D/S to thermo expansion & Misalignment joint.
	A/S Hard Mount Adapter (inside chamber)	1	Removable			50"	250"	250"	2000	Connects A/S to thermo expansion & Misalignment joint.
	Expansion & Misalignment Adapter (inside chamber)	4	Removable			36"	18'	10"	300	Compensates for thermo expansion of test vehicle and test stand
420-13450	Door Access - Docking Hatch (inside chamber)	1	Removable			35.2"	Dia.	4"	30	Substitute hatch for checkout lines when in static firing chamber.
420-13250	A/S Transporter	1	Mobile			13'	17'	18'	3200	Transports A/S to site.
420-13500	D/S Transporter	1	Mobile			10'	15'8"	18'	3000	Transports D/S to site
420-13100	A/S Hoist Sling	1	Movable			10"	53"	108"	500	Lifts A/S into static firing stand
420-13600	D/S Hoist Sling	1	Movable			10"	6'	36"	100	Lifts D/S into static firing stand
420-13260	Hoist Sling Transporter Cover	1	Mobile				192"	5'Dia.	60	Lifts transporter cover off transporter when loading or unloading LEM.

LEM EQUIPMENT - STATIC FIRING FACILITY - AMR

	PART NUMBER Figure 4.4	AREA: CONTROL BUILDING NOMENCLATURE TABLE 3.3	NO REQ'D	TYPE OF INSTALL.	FLUID REQ'D	POWER REQUIRED	SIZE H	SIZE W	SIZE D	WT. (lbs.)	REMARKS
4	410-64520	Fuel Control Station	1			115 V, 60 Cycles, 28 V DC	50"	6'	2.5'		
5	410-64560	Oxidizer Control Station	1								
9	410-62840	Pressurization Control Station	1	Fixed			50"	24"	30"		
10	410-62740	RCS Firing Control Station	1								
15	410-62800	RCS Programmer	1	Fixed		115 V, 60 Cycles 5KVA, 28 V DC 10A	6'	6'	2.5'	3000	
8	410-62220	Engine Firing Control Station	1	Fixed			50"	24"	30"		
7	410-62880	Engine Programmer	1	Fixed			84"	24"	30"		
14	410-62900	Test Conductor Control Station	1	Fixed			50"	6'	30"		
1	410-12040	Instrumentation Monitor Panel	1								

FIG 4.1

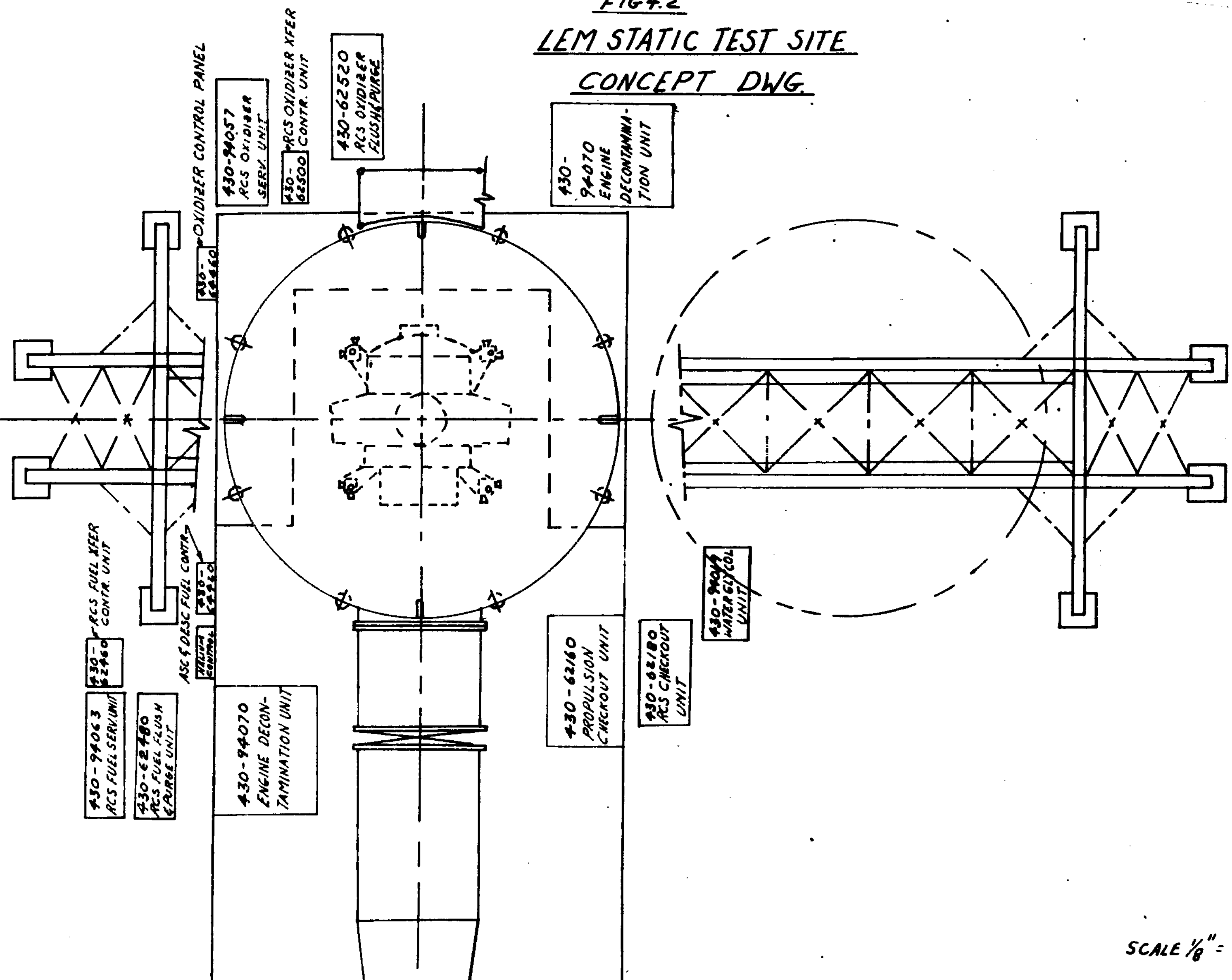
LEM STATIC TEST SITE
CONCEPT DWG.



SCALE 1/8" = 1 FOOT

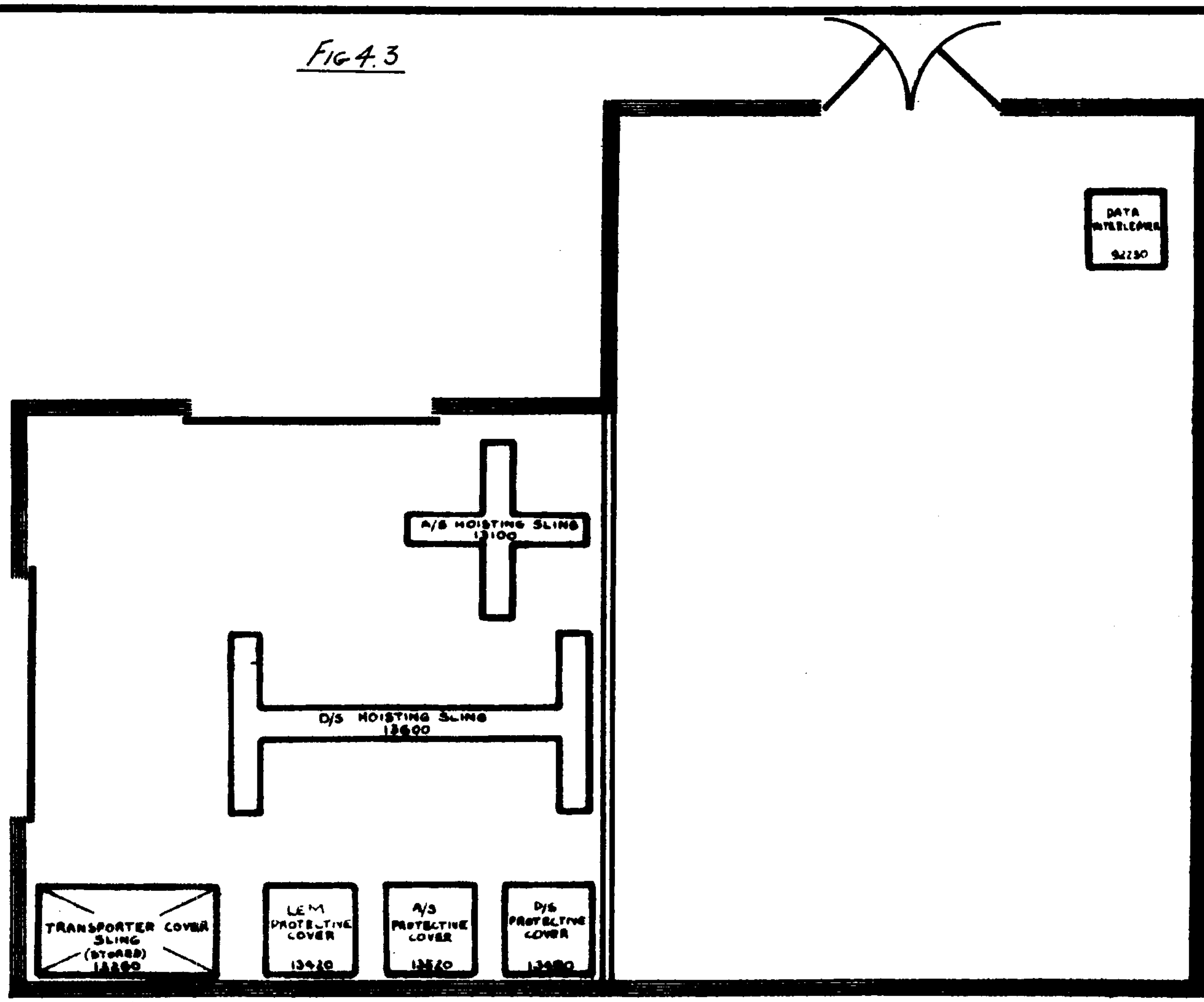
FIG 4.2

LEM STATIC TEST SITE CONCEPT DWG.



SCALE 1/8" = 1 FOOT

FIG 4.3



AMR - STATIC FIRING SITE
GSE & TRANSFER BUILDING

DRAWN J. GREEN 1-15-64
SCALE 1/4" = 1'
REV
PLANT LAYOUT
MANUFACTURING ENGINEERING
GRUMMAN AIRCRAFT ENG CORP
DWG NO.

FIG. 4.4

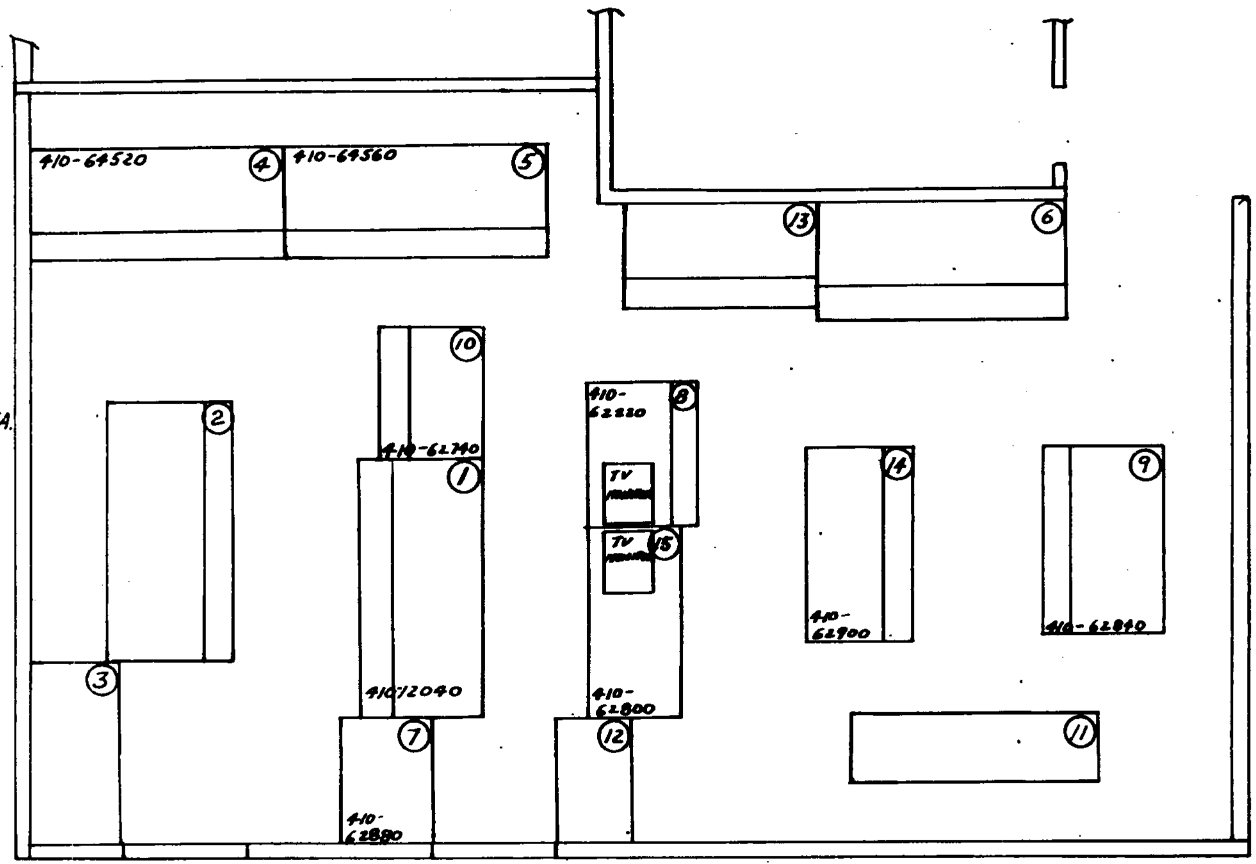
AMR STATIC TEST SITE

CONTROL BLDG

EQUIPMENT

1- INSTRUMENT MONITOR PANELS.
* 2- T.V. CAMERA CONTR. STA.
* 3- CINE CAMERA CONTR STA.
4- FUEL CONTROL STATION
5- OXIDIZER CONTROL STATION
* 6- ALT. SIMULATION CONTR. STA.
7- ENGINE PROGRAMMER
8- VEHICLE CONTROL STATION
9- PRESSURIZATION CONTR. STA.
10- RCS CONTR. STA.
* 11- FACILITY INSTRUMENT STA.
* 12- METEOROLOGICAL MONITOR STA.
* 13- SAFETY CONTROL STATION
14- TEST CONDUCTOR STA.
15- RCS PROGRAMMER

* FACILITY EQUIPMENT.



SCALE 1/4 INCH = 1 FOOT

REPORT LED-2-4'B'
DATE 1/15/64

[redacted]

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E, Par. 5.1	22	LEM	NAS 9-1100	1/15/64

TYPE II DATA

REPORT

NO. LED-2-4'B' DATE: 15 January 1964

APPENDIX A

TECHNICAL CRITERIA FOR THE

ATLANTIC MISSILE RANGE

ALTITUDE SIMULATION SYSTEM

CODE 26512

Propulsion System (G)

PREPARED BY:

R M Carbee

CHECKED BY:
M. H. Dandridge
E. Scicchitano

APPROVED BY:
R. M. Carbee

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

[redacted]

[redacted]

TECHNICAL CRITERIA FOR THE ATLANTIC MISSILE RANGE ALTITUDE SIMULATION SYSTEM

1. SCOPE

1.1 Scope: These criteria establish the requirements for the design and fabrication of the altitude simulation system at the Atlantic Missile Range (AMR), Cocoa Beach, Florida.

1.2 The altitude simulation system shall be designed in modular fashion for the Ascent and Descent Propulsion stages at AMR. The system shall consist of four major subsystems:

(a) The exhaust system, including altitude chamber, diffuser, subsonic elbow section, and ejector stages.

(b) The steam generator, to provide drive media for the ejector stages.

(c) The propellant system, consisting of propellant tankage, fill and feed control equipment for the system propellants and water, gas storage and regulation equipment.

(d) The control system, which controls, monitors and indicates the performance of the overall simulation system equipment.

1.3 There shall be a Vertical Test Stand at AMR capable of accommodating the LEM vehicle. The test stand altitude chamber shall be sized to accommodate the entire LEM system.

2. DESCRIPTION OF EQUIPMENT

2.1 Altitude Chamber for AMR: The altitude chamber for the LEM vehicle shall be sized to accommodate the entire configuration less the lunar landing gear. Two GSE fixtures shall be provided. One fixture will be required for the Descent engine firing in the mated LEM configuration. The second fixture will be required to mount the ascent stage demated for the ascent engine firing test. The AMR altitude chamber should be interchangeable and compatible with the WSMR altitude chamber.

2.2 Diffuser for AMR: The basic diffuser design shall be of the center body type and shall be installed between the altitude chamber and subsonic elbow section and shall be concentric with the engine exit cone. The diffuser must perform two distinct functions. The first is to provide minimum pressure in the altitude chamber and the second is to accomplish a maximum pressure rise so as to minimize the pumping requirements of the steam ejector system throughout the operating range requirements of the rocket engines. The diffuser inlet flange shall be attached directly to the altitude chambers.

The diffuser shall be protected by a water cooling jacket designed to maintain the dimensional integrity and to prevent spot and throat overheating, burnout and distortion during the life of the facility. Provisions for low point drains shall be provided.

2.2.1 Diffuser Interchangeability Requirements: The diffuser shall be interchangeable with engine vendor static facilities and the WSMR static facility.

2.3 Sub-Sonic Elbow Section for AMR: The sub-sonic elbow section shall be installed downstream of the diffuser. This section shall have a bend or a long radius elbow to turn the gases from the vertical to the horizontal plane into the steam operated ejectors. The sub-sonic elbow section shall be protected by a water cooling jacket. The sub-sonic elbow section inlet flange shall mate with the descent and ascent stage diffuser.

2.4 Steam Ejectors for AMR: The Steam Ejector shall be compatible and interchangeable with the engine manufacturers facilities and the WSMR facility.

2.5 Steam Generation for AMR: A LOX-Alcohol steam generator shall be provided to drive the steam ejectors. It shall be rated to supply the steam quantity and quality required to operate the altitude simulation system. The steam generation system selected should be interchangeable with the WSMR facility.

2.6 Steam Generator Propellant Run and Storage Tanks for AMR: The propellant run tanks shall have sufficient capacity to perform two (2) descent stage acceptance tests. Considerations in tankage capacity shall include boil-off, decomposition and other losses. The propellant storage tanks shall have sufficient storage capacity for two (2) descent stage acceptance firings of 45 seconds duration. Provisions for filling the propellant run and storage tanks by truck delivery shall be included.

2.7 Water Run and Storage Tanks for AMR: The water run tanks shall have sufficient capacity to supply all the water required (cooling water for diffuser, injection water, etc.) to perform two (2) descent stage acceptance test firings. The water storage tanks shall have sufficient capacity to supply all the water required to perform two (2) acceptance test firings.

2.8 Pressurization System: The propellant and water transfer shall be made with a suitable nitrogen pressurization system. System pressure and line sizing will be a function of steam generator requirements.

2.9 Control Systems for AMR: Remote manual and automatic starting and stopping of the steam generation system shall be provided. The controls and instrumentation shall be located at one panel in the

Control Center. The instrumentation accuracy shall be 1/4 of 1% throughout the complete range. The panel shall incorporate all of the necessary switches, indicating lights, relays, to operate, monitor, test and check out the system in any mode of operation. The control system shall include all necessary safety monitoring provisions so that vehicle and system are protected upon steam or power failure. The control system shall be simple, with minimum number of manual operations required. Provisions for the replacement of components, adjustments, and other required "trouble-shooting" shall be incorporated into the design so that they may be readily accomplished.

3. DIFFUSER-EJECTOR PERFORMANCE REQUIREMENTS

3.1 Descent Engine Parameters

3.1.1 The Diffuser-Ejector System shall operate, to the conditions prescribed in these specifications with the following engine parameters:

Thrust (Maximum)	10,500 pounds +10% -3%
Thrust (Minimum)	1,050 pounds +10% -3%
I_{sp} at Minimum Thrust	285 sec.
I_{sp} at Maximum Thrust	305 sec.
Gimbaling	± 6°
Gimbal Point Location	Nozzle Throat
Chamber Pressure at Maximum Thrust	113 psia
Chamber Pressure at Minimum Thrust	11.3 psia
Nozzle Exit to Throat Area Ratio	50
% Bell (Based on Equivalent of 15° Half Angle Conical Nozzle)	73
Exit I.D.	58 inches
Exit O.D.	60 inches
Length (Gimbal Point to Nozzle Exit)	69.32 inches

3.1.2 The composition and flow rates of the engine exhaust gases cover the following ranges:

COMPOSITION	MASS FLOW #/SEC Max.	Min.
H_2	.668	0.0690
CO	1.190	0.1236
CO_2	7.859	0.8110
H_2O	9.318	0.9749
N_2	15.366	1.586
He		0.0356
Total	34.400	3.6000

3.1.2.1 The following physical and thermodynamic properties of the exhaust gas shall be used in the analysis of this Diffuser-Ejector System.

Ratio of specific heats (Frozen Gamma at $\epsilon = 2$) 1.245
Molecular weight ---------------------------------- .44
Specific heat ------------------------------------- .39 BTU/lb/°F
Total Temperature --------------------------------- 5125 °F

3.1.3 The descent engine will have capabilities to throttle from the maximum flow rate of 34.40#/sec. to the minimum flow rate of 3.60#/sec. in a period of one second. Minimum flow rate to maximum flow rate throttling is also accomplished in a period of one second. Intermediate throttling conditions will be accomplished in proportional amounts of time.

3.1.4 The exhaust nozzle exit static pressure will vary from a maximum of 0.163 psia to a minimum of 0.016 psia, the lower pressure occurring with the lower chamber pressure in the design of the system.

3.1.5 The descent engine nozzle has a collapsing pressure limitation of 0.05 psi imposed as a differential pressure across the radiation cooled skirt.

3.1.6 Duration of Test Firing: The total duration of test firing the descent propulsion system at AMR shall be 45 seconds.

3.2 Ascent Engine: The ascent engine operates within the following design parameters:

a) Expansion ratio = 40:1; Exit diameter of nozzle = 31.27 inches; Total length of ascent rocket engine = 51 inches.

b) Chamber pressure; steady state at nominal thrust = 100 psia.

c) Thrust after 5 sec at nominal engine inlet pressure and propellant temperature = 3,500 ± 2.5%.

d) Thrust; end of duty cycle operating time = 3500 + 7% - 2.5%.

e) Mixture Ratio ($^{Wo}/Wf$); 1.6 ± 1.7%.

f) Isp minimum, max. thrust - end of duty cycle operating time = 306.34 sec. (3σ value) $\frac{\text{lb.f sec}}{\text{lb.m}}$

g) Oxidizer - Nitrogen Tetroxide (N_2O_4) conforming to specification MIL-P-26539.

h) Fuel - Specification MIL-P-26539. An actual mixture by weight of Hydrazine and unsymmetrical dimethylhydrazine (UDMH) conforming to Specification MIL-P-27402.

i) Start Characteristics: The rocket engine will develop 90% rated thrust within 0.200 seconds after onset of electric signal.

j) Shutdown Characteristics: The rocket engine will accomplish thrust decay to 10% rated thrust within 0.200 seconds after receipt of command signal.

k) Impulse Repeatability: The rocket engine start and shutdown characteristic shall be repeatable to provide a predictable total impulse accuracy of ± 35 lb. sec.

l) Stability: The transient starting combustion chamber pressure will not be greater than 110% of the nominal rated combustion chamber pressure. There will be no cyclic or periodic chamber pressure oscillations which exceed ± 2%, after start and during the period of effective steady-state operation.

m) Starting: Normal starting shall be accomplished at the nominal thrust level.

n) Thrust Vector Alignment: The thrust vector shall pass within a cylinder of 0.125 in radius about the engine reference line.

NOTE: 1) The thrust vector location is defined as the spatial position of the resultant reactive force of the rocket engine during operation.

2) The engine reference line is defined as a line perpendicular to a plane established by the thrust mount surface and passing through the centroid of a circle defined by the thrust mount locations.

3.2.1 **Duration of Test Firing:**

a) The total duration of test firing the Ascent propulsion system at AMR shall not exceed 20 seconds.

3.2.2 The Ascent engine nozzle has a collapsing pressure limitation of 0.1 psi imposed as a differential pressure across the engine skirt.

4.0 ALTITUDE REQUIREMENTS

These requirements are applicable to both the descent and ascent propulsion stages.

a) Starting at Pc (max.) 105,000 feet (minimum).
b) Running at Pc (max.) 105,000 feet (minimum).
c) Running between Pc (max.) and Pc (min.) Nozzle full (minimum).
d) Restarting at max. Pc: 105,000 feet (minimum)
e) Non-operative periods (vacuum soak) 105,000 feet (minimum).

5.0 SYSTEM REQUIREMENTS

a) The system shall be of the type or one similar that has been in successful operation for a minimum of one year and which will require no development.

b) The system shall be designed to have a usable life of five (5) years except for those portions that are exposed to excessive corrosion or erosion in which case minor periodic maintenance shall be required.

c) The exhaust system shall provide means to prohibit recirculation of rocket exhaust gases over the test vehicle during start, normal operation, shut down and restarts.

d) The system shall be capable of being placed in operation and attaining the desired altitude in 30 seconds maximum using the steam ejector.

e) The system shall be designed to minimize the effect of exhaust gas toxicity. The atmospheric exhaust point shall be located to maximize natural dispersement of toxic fumes.

f) The system shall not operate in vibration frequency ranges that will generate adverse noise problems or cause malfunction of the test vehcile other than those normally encountered in test vehicle operation.

g) The system shall be designed to provide for safe shutdown in event of a test vehicle malfunction or electrical power failure without damage to test vehicle.

h) The system shall be designed for minimum maintenance.

i) The system shall be designed to be self-contained and independent of external facilities except for supporting utilities such as water, power, gas (inert) and a control center.

j) The system shall be capable of performing two (2) descent stage acceptance test firings in a twelve (12) hour period.

k) Manual control of the injection water used to cool the hot gases shall be provided to override the automatic system.

l) All materials shall be compatible with Nitric Acid for limited periods of time.

m) The system shall be designed to an ambient pressure of 14.7 psia.

n) The procurement of the Altitude Simulation System for AMR shall be from one Vendor who shall have the complete system responsibility for fabrication, installation, checkout and training of personnel to operate facilities.

o) Diffuser, Ejector and Steam Generation system should be compatible and interchangeable with the Engine Manufacturers and the WSMR facilities.

p) The Diffuser-Ejector system should be one unit sized for the descent engine. Such a diffuser will also accommodate the ascent engine.

[redacted]

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E, Par. 5.1	22	LEM	NAS 9-1100	1/15/63

REPORT

NO. LED-2-4'B'
APPENDIX B

DATE: 15 January 1964

REACTION CONTROL SUBSYSTEM
ENGINE PARAMETERS

CODE 26512

Reaction Control Subsystem
PREPARED BY:

S. Portegal
CHECKED BY:
S. Portegal

O S Williams
APPROVED BY:
O. S. Williams

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

This document contains information affecting the national defense of the United States, within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

[redacted]

1.0 INTRODUCTION

The RCS engine parameters and operating information required for the design of the Static Test Facility, including a collector or separate exhauster system, are presented herein.

2.0 REACTION CONTROL SUBSYSTEM

2.1 Engine Parameters

Thurst Chambers	16 (4 clusters of 4 chambers each).
Chamber Wall Temperature (Radiation Cooled)	2800°F
Chamber Material	Molybdenum
Oxidizer	$N_2 O_4$
Fuel	50/50 Mix $N_2 H_4/(CH_3)_2 NNH_2$
Expansion Ratio (each chamber)	40:1
Throat Diameter	.865 inches
Throat Area	.59 sq. inches
Exit Diameter	5.47 inches
Exit Area	23.6 sq. inches

2.2 Thrust Chamber Characteristics

Steady State

Thrust	100 lbs ±5%
Chamber Pressure	90 psia
I_{sp}	300 seconds
Run Duration	500 seconds
Starting Transient	.013 seconds to 90% rated thrust
Shutdown Transient	.013 seconds to 5% rated thrust
Total Flow Rate per Chamber (Max.)	.33 lbs/sec
Mixture Ratio (Oxidizer/Fuel)	2:1

Pulse Mode

Minimum Pulse Duration	.010 seconds
Pulse Frequency	up to 25 cps

2.0 REACTION CONTROL SUBSYSTEM

2.2 Thrust Chamber Characteristics

Pulse Mode - continued

Average Chamber Pressure for a Minimum Pulse ---------------------- 50 psia

Average Flow Rate for a Minimum Pulse - .55 lb/sec

Minimum Impulse Bit ------------------ .5 lb/sec ± .1 lb/sec

Pulse Mode Duration ------------------ 500 seconds

2.3 Exhaust Gases and Flow Rates: The composition and flow rates of the exhaust gases from one individual thrust chamber in a steady-state mode cover the following ranges:

Composition	Mass Flow Rate (#/sec)
N_2	.1426
H_2O	.1052
OH	.00968
H_2	.00201
CO	.0291
CO_2	.0367
O_2	.0073
H	.0003
	.33298 #/sec Total

The following are the physical and thermodynamics properties of the RCS exhaust gases.

Ration of Specific Heats -------------- 1.30

Modecular Weight ---------------------- 21.991

Specific Heat ------------------------- .386 BTU/lb/°F

Total Temperature --------------------- 5629°R

2.4 Tests Planned: Acceptance tests at AMR will consist of steady-state running and pulse mode operation simultaneously. The total firing time required for these planned tests will be 240 seconds. During the planned firing the maximum exhaust efflux will be 1.98 lbs/sec, based on four chambers steady-state and four chambers pulsing.

Code 26512 Eng-23A